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THE 1983-1984 EVALUATION OF VAS DATA IN THE LFM

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1. Introduction

This paper examines the effect of vertical profiles of temperature from the VISSR Atmospheric Sounder (VAS) aboard the GOES-6 upon numerical integrations of the operational version of Limited Fine-mesh Model (LFM) run routinely at the National Meteorological Center (NMC). Studies of this kind are often called "impact studies" and have been conducted in the past with regard to the effect of temperature sounding data from polar orbiter satellites upon hemispheric or global analyses and forecasts. Bonner, et al. (1976) concluded that VTPR data from the NOAA-2 satellite produced, at most, a slight improvement on hemispheric forecasts out to 48-hours. He further concluded this result to be due to the lack of VTPR data in meteorologically active region, such as baroclinic zones, where the existence of deep clouds normally preclude valid clear radiance measurements, Tracton, et al 1980, concluded that TIROS-N data reduced the spatial variance of hemispheric analyses of height and temperature. These studies all focused on VTPR or TIROS-N data, which were designed to be capable of resolving synoptic-scale features. VAS, on the other hand, was designed to describe atmospheric temperature and moisture profiles with spatial and temporal resolutions of about 90 km and one hour, respectively. Because VAS is stationary with respect to the earth's surface, soundings must be made over a limited area. This makes VAS a natural choice for use in limited area models, such as the LFM, and for delineating pre-convective environments. In preparation for such uses of VAS data, Chesters, et al., 1982 conducted a simulation study to determine whether the meteorologically useful results could be achieved. They concluded that VAS would indeed hear sufficient horizontal resolution to adequately describe the major features of severe storm enviornments. They further emphasized that the quality of the soundings in the lowest levels would be improved by using surface observations in calculating VAS radiances.

In a previous impact study O'Lenic (1985a) examined the effect of VAS temperature profiles upon six LFM 48-hour forecasts. As in the current work, the VAS soundings were inserted in the LFM analysis (Cressman, 1959) over a limited region of the Pacific off the west coast of the United States. Comparisons of the forecasts which used the VAS data ("VAS forecasts") with forecasts which did not ("NOVAS forecasts") indicated that four of the six VAS forecasts of 500 mb height bore moderately reduced error levels as compared to the NOVAS forecasts, while none of the forecasts in which VAS data were used were degraded.

While the algorithm used to retrieve soundings from VAS radiances for the current study is the same as that used in the earlier one, (hereafter referred to as simply 1985A) there are some important differences. The VAS soundings used in these experiments were prepared at the Cooperative Insitute for Meteorological Satellite Studies (CIMSS), at the University of Wisconsin, in Madison. The retrieval technique (Smith, 1970) inverts the radiative transfer equation via an iterative process requiring three sets of information. One is an initial estimate of the atmospheric temperature profile. The closer this initial estimate of the temperature profile is to that of the actual atmosphere, the more accurate will be the retrieved soundings. In 1985A CIMSS used the LFM 12-hour forecast, valid approximately at the same time as the VAS retrievals, as the initial estimate. This was a logical choice, since the LFM 12 hour forecast was available at the time it was needed. However it is also incestuous to the extent that using the LFM 12-hour forecast institutionalizes any biases inherent in the LFM in the retrieved soundings, muddying any ensuing evaluation of the quality of the data. Phillips (1979) discussed this problem in regard to retrieving polar orbiter data. CIMSS responded to this objectionable circumstance by preparing an independent 3-

dimensional analysis of atmospheric temperature for use as the initial estimate to the retrieval algorithm (Hayden and Schreiner, 1984). They used a Cressman type system to analyze temperature data from the polar orbiter collected a minimun of six hours prior to the valid time of the VAS data. Thus, the first guess for the VAS retrievals was always at least six hours old, and must be considered to be possible source of error in the retrieved soundings.

Another piece of information required by the retrieval algorithm is an estimate of the surface skin temperature, which is used to correct or exclude radiance measurements which may be contaminated by clouds. For this study, CIMSS chose to use the NMC 1000 mb temperature forecast valid at the time of the VAS data (12 GMT) updated with ship data valid at 0600 GMT. Hayden and Schreiner (1984) report that this part of the retrieval system could also have been a source of error in the retrieved soundings, since, because of the assumed inaccuracy of the skin temperature field, the cloud contamination threshold was set at a high value of 10 degrees. The data prepared by CIMSS for 1985A simply used the non-updated NMC forecast of 1000 mb temperature for this purpose.

The third piece of information required by the retrieval algorithm is the set of clear radiances. These consist of statistically averaged sets of individual observations or individual fields of view (IFOV) as they are called. The resulting set of clear radiances, when combined into an "image" or field is capable of representing features in the temperature field with a minimum horizontal scale of about 90 km.

The retrieval system comprised by the algorithm and the three elements just discussed was designed so as to be essentially automated. CIMSS did this in order to improve the through-put of soundings. The retrieval system used for 1984A was not automated, and hours, or days, instead of minutes, were required to produce a set of soundings. The soundings of 1984A were also more extensively edited by human beings than those of the current study, which were objectively edited by "buddy checks", i.e. comparison of a sounding with its neighbors, but which were not extensively edited by humans.

The automated system developed by CIMSS was developed, in part, to examine the feasibility of using VAS data operationally in the LFM. It should be noted that such an undertaking can be done only under very stringent time constraints. Such constraints preclude extensive editing of data by humans. They also require the pragmatic use of data that are available, and not necessarily ideal. CIMSS coordinated data acquisition, processing, and transmission among three diverse entitites: NESDIS Command and Data Acquisition Station (CDAS) at Wallops Island, Virginia, CIMSS in Wisconsin and NMC in Washington, DC. The test of the system developed by CIMSS to do all this was undertaken between 28 November 1983, and 15 February 1984, with attempts to collect and process data to be made twice per week.

In selecting cases for this evaluation, an attempt was made to select cases which included a variety of 500 mb flow pattens, and especially cases in which changes in the flow pattern off the West coast wee in progress, or about to occur. Unfortunately, a large number of cases contained uninteresting upper air ridges. Thus, only about half of the total number of cases collected are examined in this paper.

2. The Analysis and Forecast System

The LFM analysis system produces independent analyses of the meteorological variables at 1000 mb and 300 mb by the method of successive corrections. The lapse rate defined by these analysis in this layer is then used to analyze the data of the other mandatory levels (Cressman, 1959). At locations where data is absent between these levels or above 300 mb, the first guess is preserved in the analysis. This feature is of interest because the VAS temperature data is admitted to the analysis in the form of thicknesses, which are in turn converted to heights by adding the value of the 1000 mb height analysis to the column of thicknesses of which a sounding is comprised. Such a procedure is also used to analyze TIROS-N data in global analysis systems. However, in those systems satellite data is weighted so that it has a smaller influence on the analysis than other data, radiosondes for example. Such is not the case for VAS data admitted to the LFM in these experiments. Here VAS data is weighted equally with radiosonde, or aircraft data.

The model used is the operational version of the LFM, as described by Gerrity, 1976, and Newell, 1980.

Section two of this paper describes the procedure used to evaluate VAS data in the LFM. Section three contains the overall results of the eight experiments conducted. In Section four, three cases are examined in detail in order to shed light on the means by which the VAS data impacts the forecasts. Section five gives a summary and conclusions.

3. Procedure

For each case, the VAS sounding data, along with the conventional data were analyzed on the LFM grid via the method of successive corrections, followed by an initialization, in which the constant pressure analyses are interpolated to sigma surfaces. Such an initialized analysis, having been interpolated back to a constant pressure surface, is shown in figure 1. The automated system used by CIMSS to edit this data is responsible for the irregular spacing of the soundings. Regions containing no observations coincide with clouds.

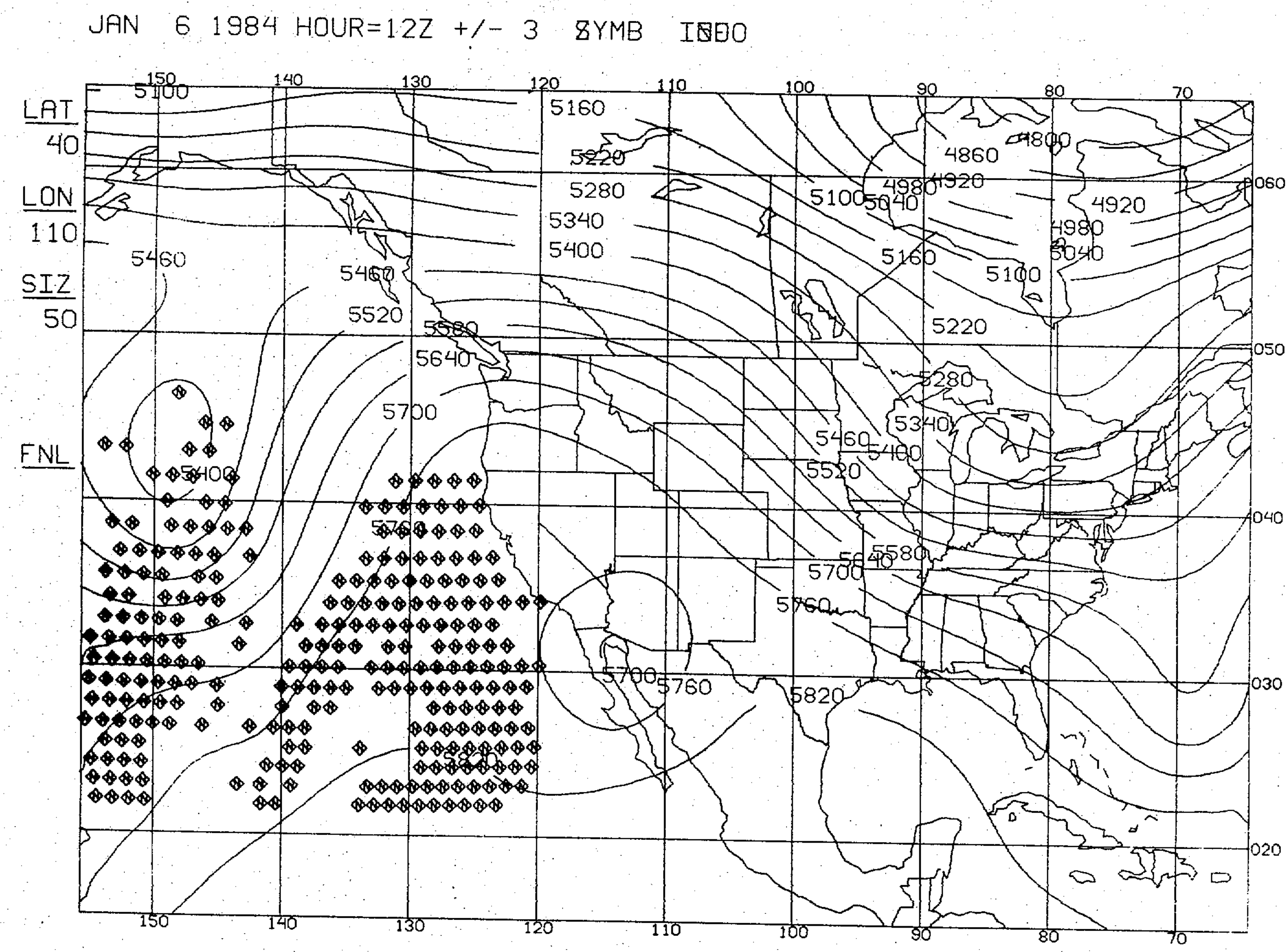


Figure 1. 500mb LFM height analysis using both VAS and conventional data, valid 12 GMT 6 January, 1984. Location of VAS observations is marked by diamond symbols.

For each of the eight cases, initialized fields were prepared for all variables and all levels of the LFM. The model was then used to generate forecasts out to 48 hours.

The forecasts were evaluated through the use of sequences of forecast error maps, and gross error statistic including the S1 score (Teweles and Wobus, 1954) the rms error, and the mean error (Panofsky and Brier, 1968). A gross error statistic is one which represents the average of all of the individual, or point values of the statistic over an entire area of interest. Such statistics sacrifice specificity for conciseness, since they are used to represent results of an entire forecast map. The gross statistics used in the current study are computed from station data from a 110 station network encompassing mainly the land portions of North America.

4. Comparison of 48 Hour Forecasts With and Without VAS

Forecast error maps of 500 mb heights, derived by taking the arithmetic difference between LFM 48-hour forecasts and the verifying analyses, are shown in figure 2 A-H. The differences apparent in the error contours between the NOVAS and the VAS forecasts must be due solely to the difference in the initial analyses caused by the VAS data. In general, the VAS data induces differences between VAS and NOVAS 48 hour forecasts of the order of 60 meters in the 500 mb heights. While such differences do occur in the immediate vicinity of the original location of the data, changes just as large or larger occur to the east, over the western, central, and even the eastern USA. The propagation of the information from the VAS data to regions over the western and central USA can be explained by advection at the speed of the wind, and by group velocity propagation. For small and medium wavelength perturbations, such as those which characterize cases A, B, as D, F, and G, the group velocity of Rossby waves

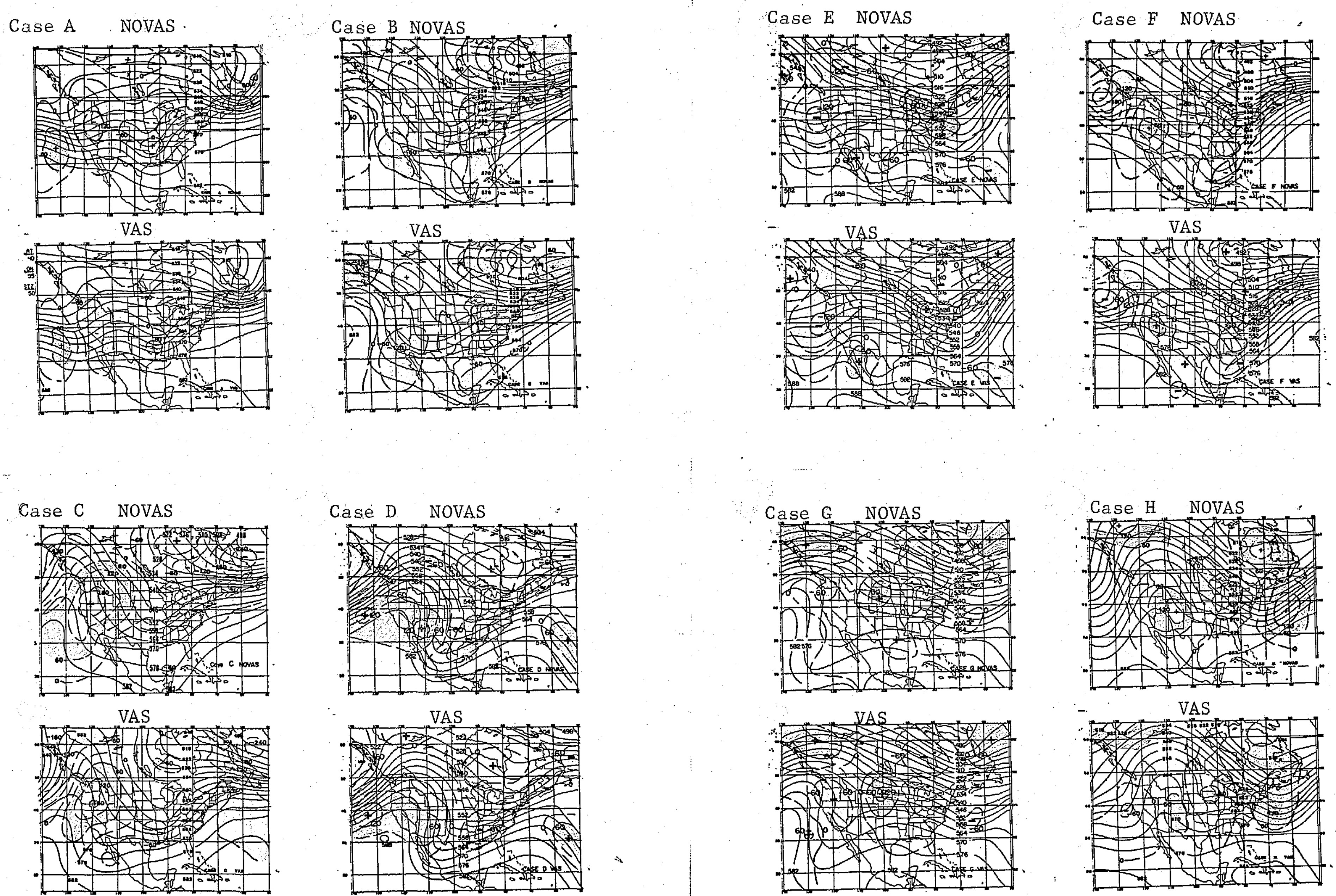


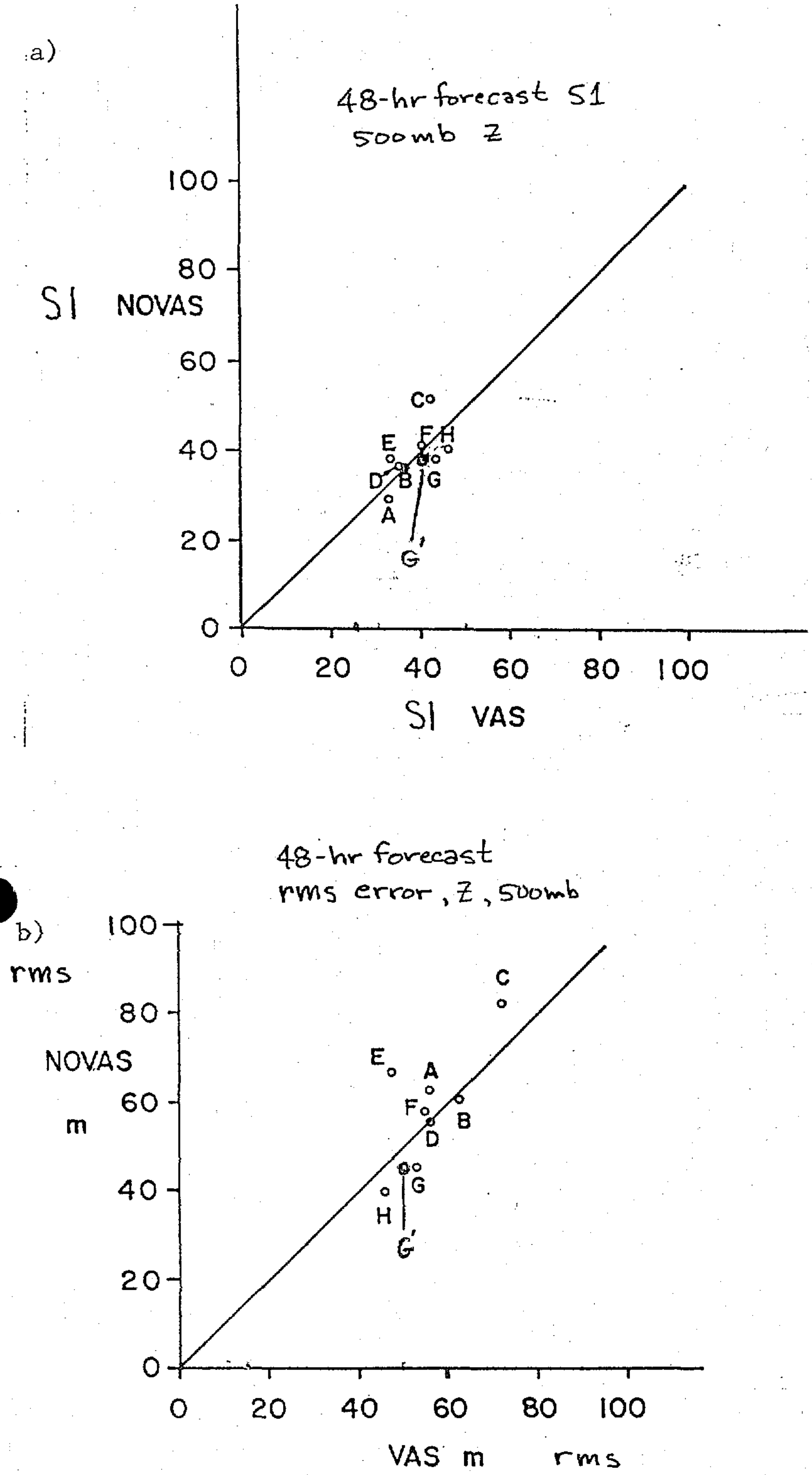
Figure 2. LFM 48 hour 500mb forecast height errors (dashed contours, 60 m intervals), and 500mb heights (solid contours, decameters) for NOVAS and VAS forecasts.

exceeds the phase velocity by, at most, 20 percent. However these group velocities cannot account for the scale and location of differences between VAS and NOVAS error maps seen in cases C, E, and H (figures 2C, E, H). In these cases, over large portions of the eastern U.S., the VAS forecast improves upon the NOVAS 48 hour 500 mb height forecast by more than 60 meters. The time and space scale of these differences suggest that a wave disturbance, perhaps an external gravity wave, an external Rossby wave, or a combination of the two is responsible for the observed differences. This hypothesis will be further examined in a later section of this paper. Table 1 summarizes the results of subjective evaluation of the error maps (figures 2 A-H) for the VAS 48 hour forecast. Cases C, D, E, F, and H are judged to be slightly to moderately improved, while the case G VAS forecast is degraded, and in cases A and B, the results are ambivalent, appearing to be improved in one location and degraded in another on the same forecast chart.

Table 1. Summary of Experimental Result Based on Forecast Error Maps

Case	Impact Location	Magnitude of Impact	Result
A	W, Cent. US	60 m	Mixed (W improved, Cent. degraded)
B	Entire US	60 m	Mixed (W degraded, E improved)
C	Entire US	60-100m	Improved everywhere
D	W, Cent. US	60 m	Improved in West
E	Entire US	60 m	Improved everywhere
F	W, Cent. US	30-60 m	Improved in Cent. US
G	Entire US	60 m	Degraded in Cent. US
H	Entire US	60-70 m	Mixed (improved SW, Cent. US, degraded East)

While the use of forecast error maps has helped to point out which forecasts were clearly improved or degraded by VAS data, we are still left with a need to quantify the degree of error. This is especially true in cases such as those represented by cases A and B, where the error maps cannot be easily interpreted. It is for these reasons that verification statistics such as the S1 score and the rms error are useful as evaluation tools. The results of the gross statistical evaluation for cases A-H are shown in figures 3A,B. In general, the results shown correspond to our expectations based on the forecast error maps shown earlier (figures 2 A-H), but there are a few notable exceptions. One of these is case D, for which figures 3A,B show essentially no difference between VAS and NOVAS forecasts despite the clear improvement seen in the VAS forecast over the western US on the forecast error maps (Figure 2D). This result may be due to the relatively small number of radiosonde stations over the southwestern US, since the gross statistics are calculated at the locations of those stations. Another case in which the gross statistics and the error maps seem to disagree is case H. Despite clear evidence of the superiority of the VAS forecast in figures 2H, the corresponding S1 and rms scores indicate a degradation. While moderate improvements appear to occur over the southwestern and north-central US (Figure 2H), note that the largest improvement in the VAS forecast occurs over northeastern Canada and over the Atlantic, where there are few, if any upper air observing stations. Also, despite this observed reduction in error off the east coast of the United States, the region bearing errors in the VAS forecast is shifted westward, so that it lies directly over the east coast. Thus, though the amplitude of the forecast error is reduced especially over the Atlantic where there are upper air observing stations to record the event, the error does increase over the eastern US coast where a relatively high concentration of stations is situated.



LEGEND

case	Date of initial analysis
A	09 December 1983
B	10 January 1984
C	11 January 1984
D	18 February 1984
E	06 January 1984
F	09 January 1984
G	31 January 1984
H	06 February 1984
G'	31 January 1984 **

** results of forecast from specially edited data set for 31 January case.

Figure 3. S1 scores, LFM forecasts of surface pressure (a), and 500mb height (b) rms error for 48 hour forecasts.

The foregoing evaluation of the impact of VAS data shows that

1) VAS data improved upon NOVAS in at least half of the forecasts;

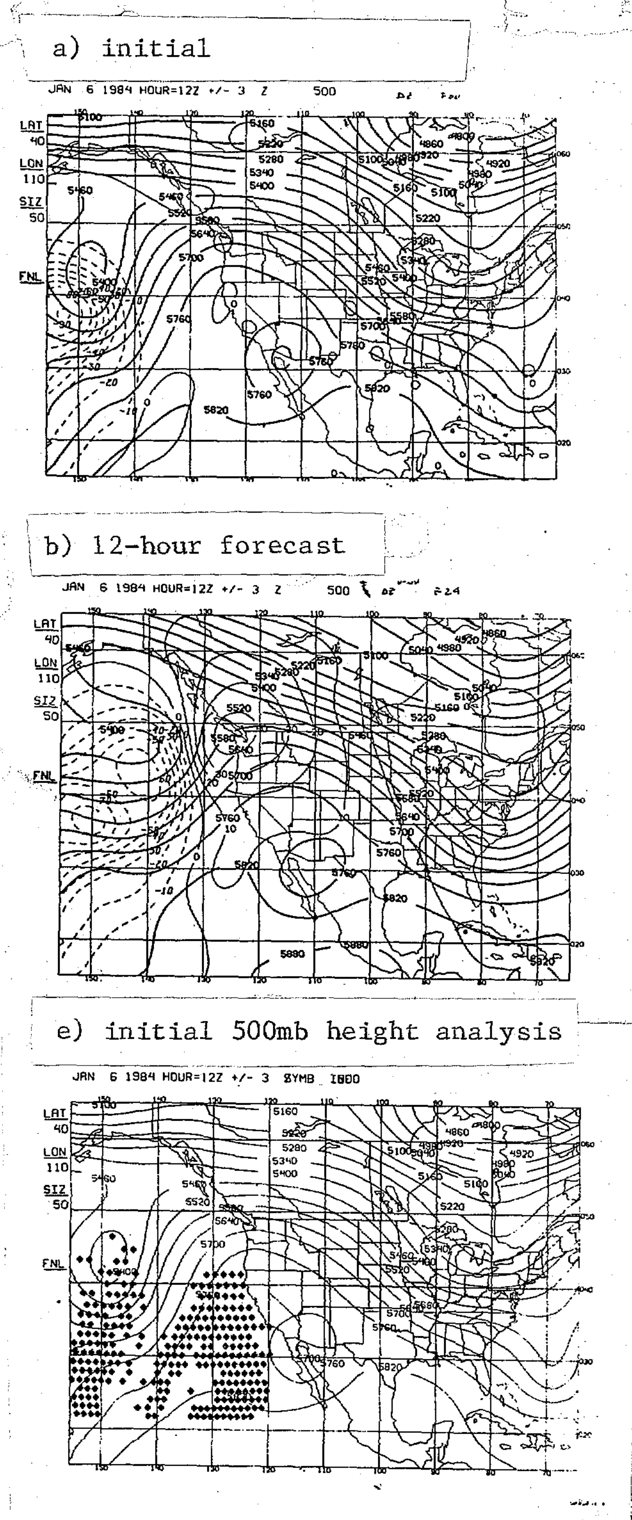
2) in most cases examined, the impact of VAS data upon 48 hour forecasts of 500 mb height were in the moderate (+/- 60 meters) range;

3) the 500 mb height change in the only forecast which was overall degraded by VAS data (Case G) was about 60 meters, again, in the moderate range.

5. Propagation of Forecast Difference

Several of the experimental integrations of the LFM model will now be examined in detail in order to illustrate the manner in which VAS data actually influence the forecasts. This will be accomplished by directly comparing the VAS forecasts with the NOVAS or control forecasts at various intervals out to 48 hours. Since the two types of forecasts differ only in their use or non-use of VAS data, any differences between forecasts must be due solely to the presence of VAS data, and its handling by the model.

The first case to be so examined is Case E, shown in figure 4. Panel A shows the 500 mb height field at the initial time of the forecast. The VAS-minus-NOVAS 500 mb height difference field appears at the western boundary of the LFM domain. Panel e of figure 4 not only shows the initial 500 mb height analysis, but it also shows the locations of the individual VAS reports used in the VAS analysis. Comparing panels a and e indicates that the bulk of the impact from VAS data in this case occurs in association with the trough at 150°W. There, the VAS data render the trough up to 90 meters deeper than does conventional data, and move the trough futher west and south. The large number of VAS soundings under the ridge provide very little in the way of new information to the analysis, as indicated by the zero difference contours there.



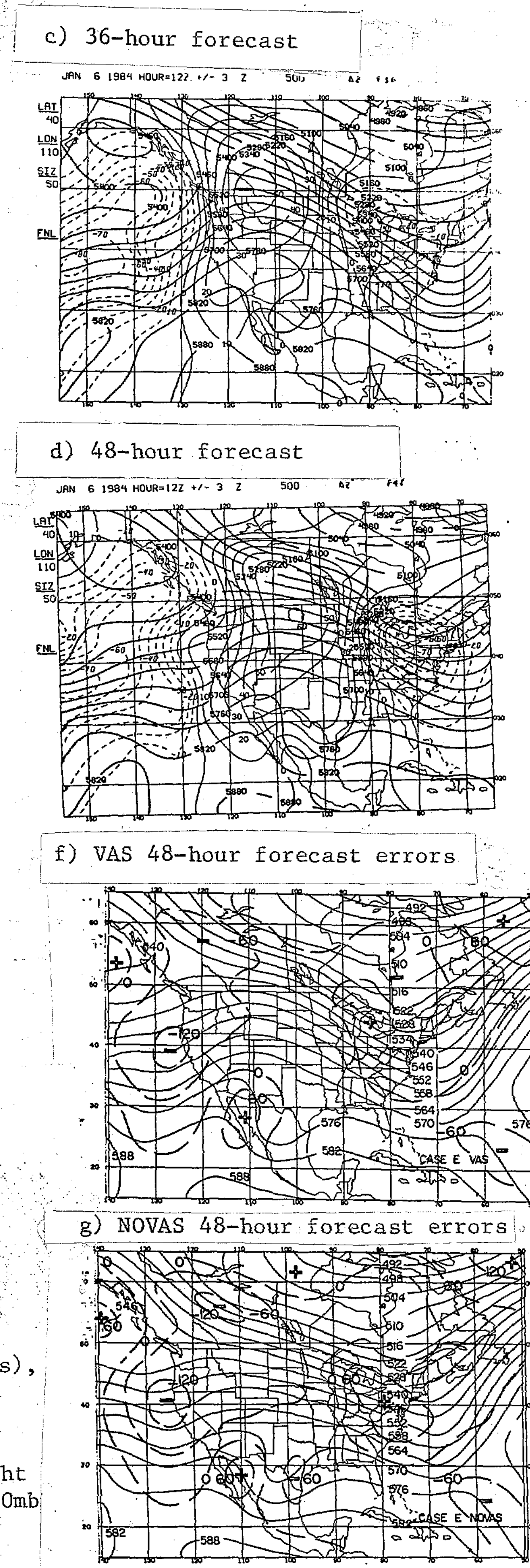


Figure 4. Forecast evolution, Case E, beginning 12 GMT 6 January 1984.
a-d) VAS forecast 500mb heights(meters), and VAS-NOVAS height differences.
e) 500mb height analysis, 12 GMT 6 January VAS observations located at diamonds.
f,g) VAS, NOVAS 48-hour forecast 500mb height errors(dashed,meters), and verifying 500mb height analysis contours(decameters).

Twenty four hours later (figure 4b), large negative 500 mb height differences extend from their initial location, near the western boundary, eastward to about 130°W, about as far as advection could carry such a perturbation in 12 hours. However, a region of positive differences appears over Vancouver, while negative differences are hinted at over the Great Lakes. These differences hint at a wave-train disturbance which propagates energy downstream.

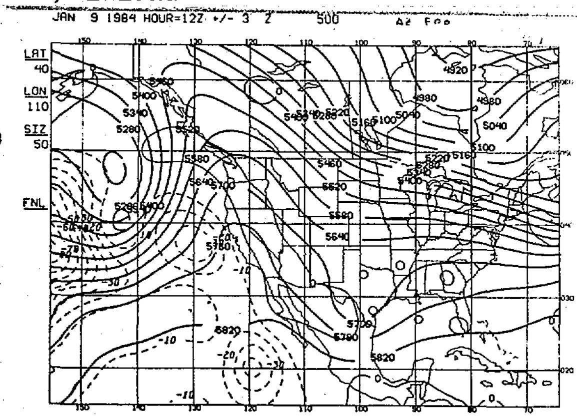
By 36 hours (Figure 4c) a large region of negative differences covers the western quarter of the domain, while those over the Great Lakes have grown to -30 meters. The positive height differences now lay over Montana, and exceed +50 meters. By this time the wave-like character of the height difference pattern is clearly apparent. Finally, by 48 hours (Figure 4d) the height-difference wave-train becomes pronounced, affecting most of the domain, with maximum height difference amplitudes of 60 to 70 meters. In just 48 hours height difference perturbations equal in size to the initial perturbations exist over the entire domain. While the perturbations over the western portion of the forecast model domain appeared initially to propagate slowly eastward, those over the eastern portion of the domain grow rapidly in amplitude but have essentially zero phase speed. These are further evidences that a wave, possibly an external gravity wave, or a Rossby wave is acting. Maps showing the changes in the 48 hour forecast wind and mass fields at 500 mb (not shown) indicate that the wind and mass fields associated with the disturbance are barotrophic and in geostrophic balance through most of the atmosphere, though a small ageostrophic component can be seen in the lower and upper levels. These maps also lend weight to the motion that a barotrophic Rossby wave, probably excited by the initial height field differences, and especially the differences along the western boundary. Maintenance of boundary differences throughout the forecast likely plays a crucial role in maintaining the wave.

The initial 500 mb height field for Case F is shown in figures 5a, e. This pattern is similar to that of case E: a large amplitude ridge is situated over the Rockies while a short wave trough approaches the Pacific coast. Also, as in the previous case, the changes introduced into the 500 mb height field by the VAS data are relatively large, up to +80 meters, and are situated at the boundary. The main initial difference is that far fewer VAS observations were available for Case F (Figure 5e). Cases G and F are similar in that the changes in the forecast due to the presence of the VAS data appear at various points downstream of the initial location of the data in the 24 hour forecast, (Figures 4B, 5B) and then grow in amplitude in each succeeding forecast. By the 48 hour forecast, (Figure 6d), the information introduced by the VAS data has resulted in the VAS 500 mb height forecast being up to 70 meters lower over the Pacific, and from 10 to 30 meters higher off Canada's Pacific coast and through the mid-section of the US than the NOVAS forecast. These modest differences are sufficient to improve the VAS forecast relative to the NOVAS forecast when forecast error maps of the two are compared (Figures 5f, g). The region of -60 meter 500 mb forecast height error extending from Kansas to the Dakotas in Figure 5g, is reduced to a very small area in Figure 5f, reflecting a reduction in the amplitude of the short wavelength trough in that region in the VAS forecast.

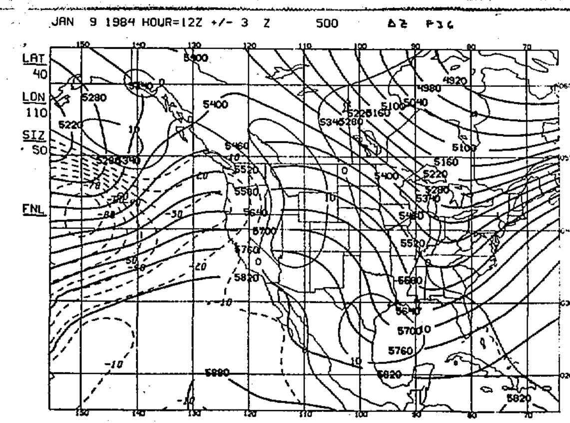
This small improvement is also reflected in the rms error statistic and the S1 score (Figures 3a, b). Comparison of VAS-NOVAS 48 hour forecast wind and height differences (not shown) indicate that the wind and mass field differences are essentially geostrophic, as was observed in case E.

The final experiment to be examined in detail is Case G, shown in Figure 6 a-g. Figure 6e shows the initial analysis of 500 mb height made using VAS

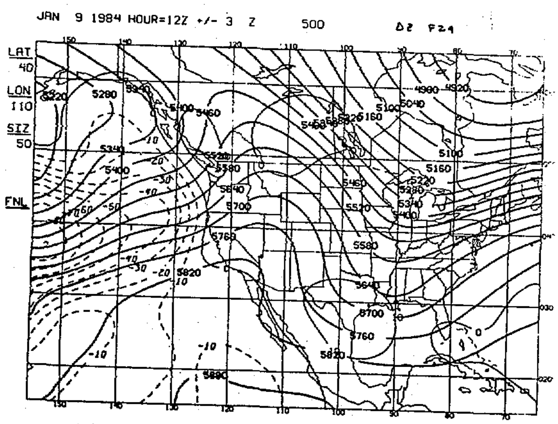
a) initial



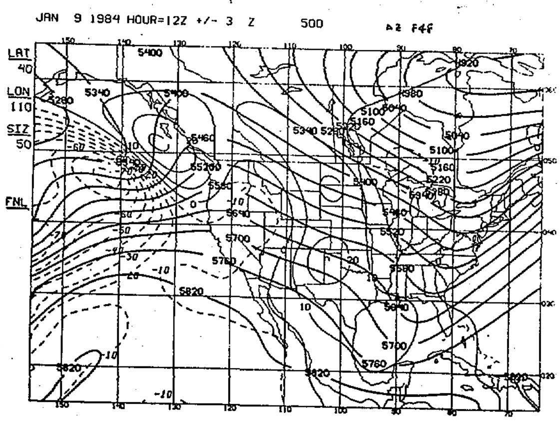
c) 36-hour forecast



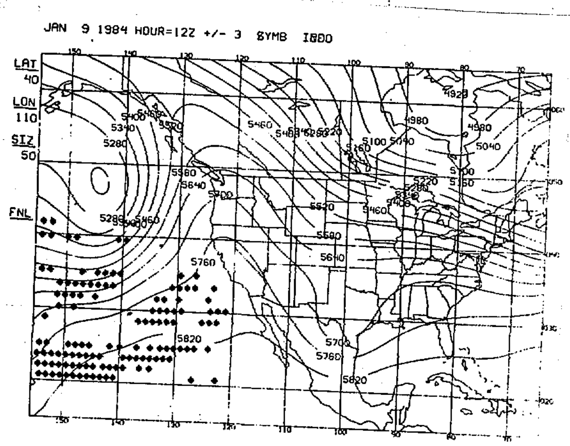
b) 12-hour forecast



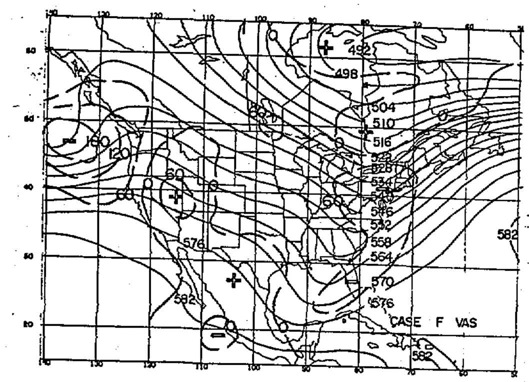
d) 48-hour forecast



e) initial 500mb height analysis



f) VAS 48-hour forecast errors



g) NOVAS 48-hour forecast errors

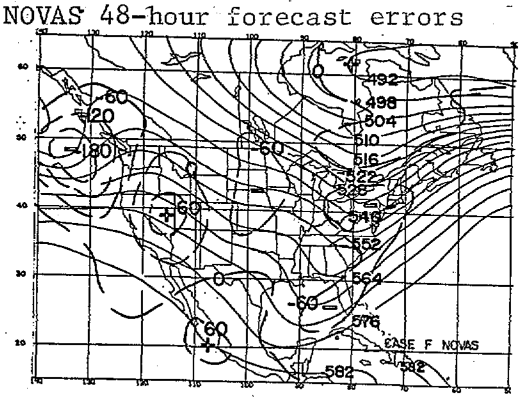
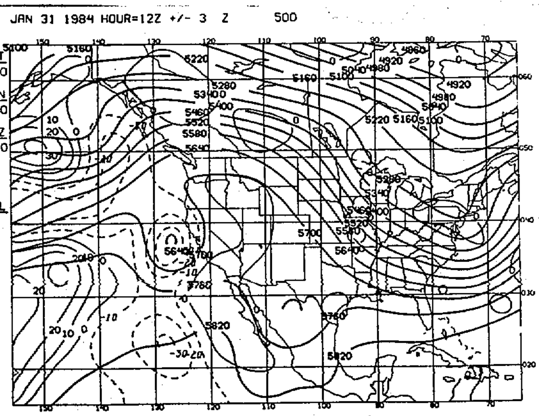


Figure 5. Same as figure 4, except for Case F, beginning 12 GMT 9 January 1984.

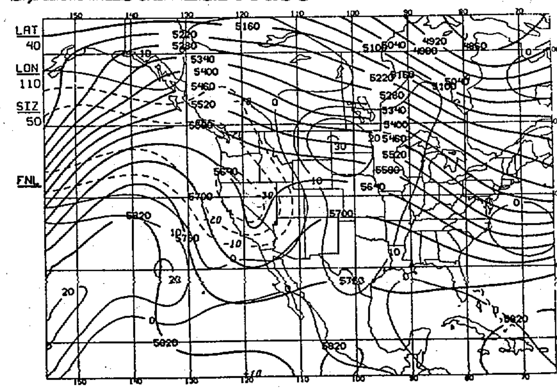
data. The diamonds show the locations of the VAS soundings. Like the two cases discussed earlier, the initial 500 mb height pattern is characterized by a medium-scale wave roughly spanning the US, and a trough along the east coast. In those two cases, the VAS and NOVAS analyses differed by up to 70 meters, and those regions of large differences were concentrated at the western boundary of the LFM domain. In case g, however, the initial height differences (Figure 6a) contain no single areas of large amplitude 500 mb height differences, but rather five, areally small, widely separated regions of analysis difference, none of which exceeds thirty meters in amplitude. Two of these areas lie along the western boundary of the LFM: a region of +10 to +20 meter differences between about 15°N and 33°N and a region of -10 to -20 meter differences between 39°N and 45°N. The region of +10 to +20 m differences near 50°N is due mainly to the single observation at 50°N and 153°W, which is not at the boundary. This latter region of differences, together with a finger of differences extending eastward and northward from the boundary, do indicate that VAS data has slightly amplified the shortwave trough near 50°N and 140°W (Figure 6A). The other feature of interest is the cutoff low west of Monterey Bay, which the VAS-NOVAS height differences indicate is made about 30m deeper by VAS data. The sequence of forecasts made from this initial analysis (Figure 6 B-D) reveals that the regions of 500 mb height difference present in the initial analysis appear to move at the speed of the features they are initially associated with, or possibly at speeds that are slightly greater than of the wind. The scale, location, and movement of these features could be explained by energy propagated downstream at the group velocity. These features are probably not associated with Rossby waves.

The clear result of the use of VAS data in this case is a moderate <u>increase</u> in error over South Dakota and the western states at 48 hours (Figures 6F, G).

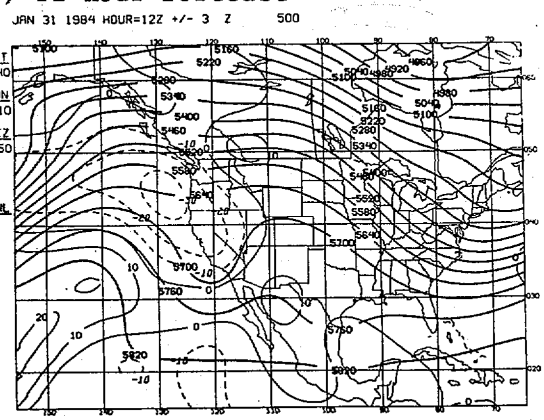
a) initial



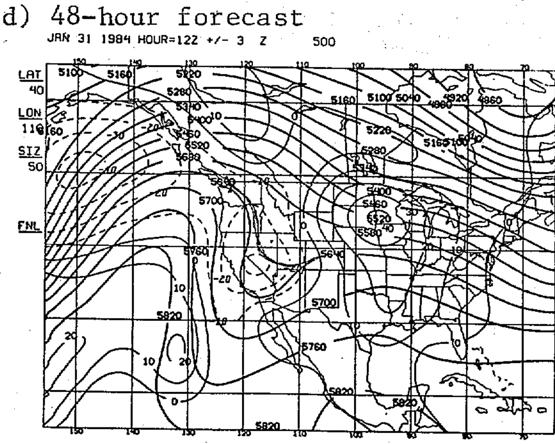
c) 36-hour forecast



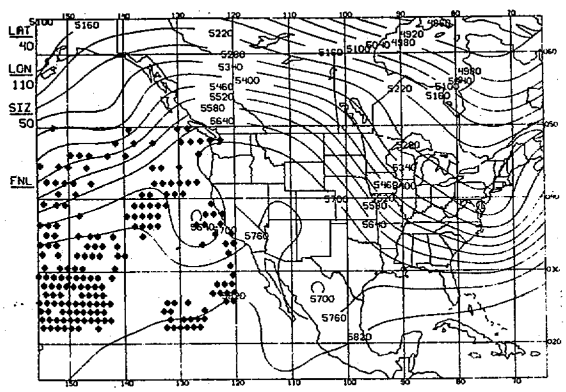
b) 12-hour forecast



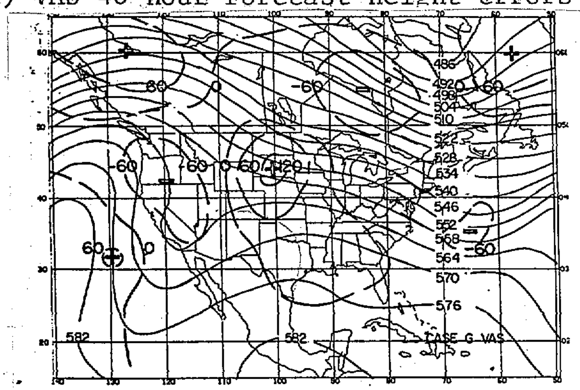
d) 48-hour forecast



e) initial 500mb height analysis



f) VAS 48-hour forecast height errors



g) NOVAS 48-hour forecast height errors

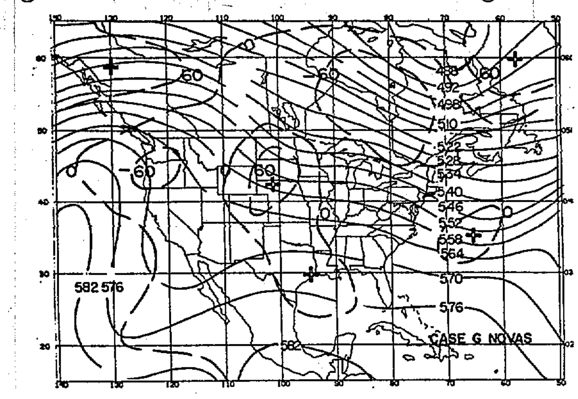


Figure 6. Same as figure 4, except for Case G, beginning 12 GMT 31 January 1984.

The VAS forecast is not as accurate as the NOVAS in handling either the short wave trough, or the layer trough to the South. The major reason for this appears to be an exaggeration of the ridge over Texas and the trough over California. A look back at the sequence of forecast maps tempts one to seek the cause of this increase in error in the handling of the cutoff low initially west of Monterey Bay. This low was initially deepened by VAS data by up to 30 meters. It is reasoned that this treatment may have maintained too strong a trough during the forecast, which in turn, built up an erroneous ridge downstream. Figure 6G indicates that a correct result would show the short wave trough nearly in phase with the California trough. However, in the VAS forecast, (Figure 6F), the trough finds itself confronted with a ridge which prevents any further deepening of the short wave, and probably actually helps to damp the wave.

In order to test the hypothesis just stated, an experiment was conducted in which VAS data in the vicinity of the Monterey low were deleted from the initial set of soundings (Figure 7F). The LFM analysis was redone using this edited data set, and the forecast model was rerun. The results of this forecast are shown in figure 7 B-E. These maps verify that the hypothesis concerning the cutoff low was partially correct: the new VAS forecast is slightly improved through slightly reduced amplitude of the California-Texas trough-ridge system. However the improvement is small, and the new forecast is still second in accuracy to the NOVAS forecast. What accounts for the yet unexplained error? One possibility is that the persistent height differences which emanate from the boundaries throughout the forecast are at fault. Another is that the relatively small initial height differences were not sufficient to excite the Rossby wave-induced changes in heights across the domain but effected changes in individual features moving at different phase speeds one or both of which

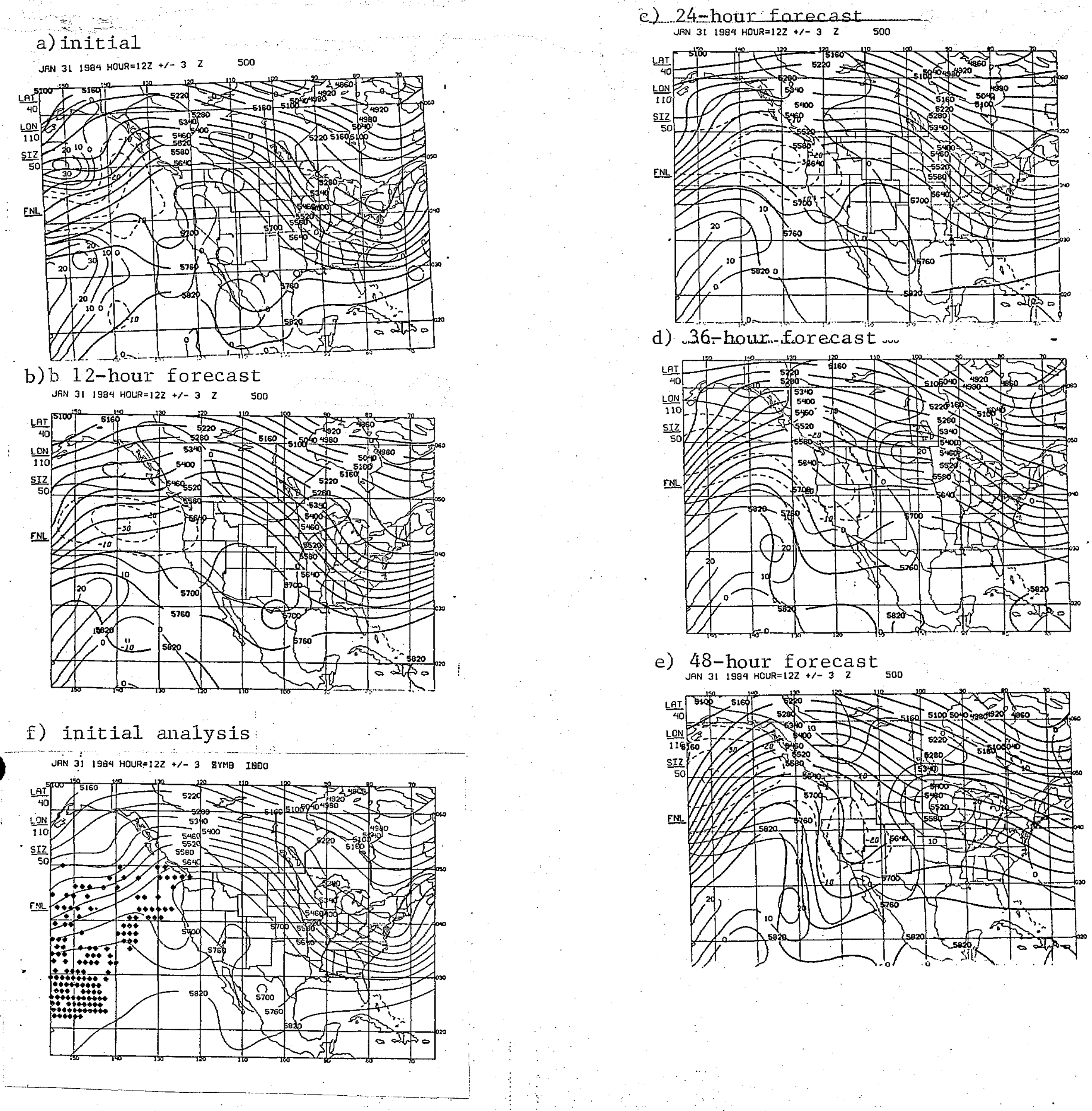


Figure 7. Evolution of Case G forecast run from an initial analysis made from specially edited VAS data.

a-d) VAS forecast 500mb heights(meters), and VAS_NOVAS forecast height differences(meters).

f) Analysis of 500mb heights valid 12 GMT 31 January 1984, with VAS data excluded between 20°N and 40°N, and 135°W and 120°W. Forecast difference contours are slightly lighter than height contours.

were either poorly represented by the data initially, or poorly handled by the forecast model, or a combination of these factors. Future experiments with improved analysis-forecast systems, and improved VAS data editing and reduction hold hope for better understanding in these areas.

6. Summary and Conclusions

The impact of VAS temperature profiles upon LFM analyses and forecasts has been examined as an indirect means of evaluating the information content of the data. The temperature soundings were processed by CIMSS at the University of Wisconsin via a new, totally automated retrieval and editing system. CIMSS took special care to avoid using any NMC forecast products to prevent biases from these products from being transferred to the VAS data and then back into the LFM. At NMC the data were combined with conventional data, analyzed, and the analyses used to initialize the LFM. Forty-eight hour forecasts of 500 mb height made from analyses containing only conventional data (NOVAS forecasts) were compared with forecasts made from analyses using both VAS and conventional data (VAS forecasts). Examination of forecast error maps, rms errors, and S1 scores of 500 mb height forecasts for eight winter 1983-1984 cases indicate that

1) VAS data impacts 48 hour forecasts of 500 mb height at most moderately (less than 90 meters difference between VAS and NOVAS forecasts and less than 60 meters in most cases). However, even though the height differences seem small, as was shown, they can have influence on weather events that NMC forecasters would find to be significant.

2) Degradation of forecast accuracy as measured by rms error and S1 scores occured for two cases (G, H), though forecast error maps for Case H indicate that its VAS forecast was actually superior to the

NOVAS forecast in terms of the accuracy of its forecast of the amplitude and phase of features.

3) Four forecasts (cases C, D, E, F) were improved by VAS data, and two of them (cases E and C) were significantly improved, as measured by rms error and S1 score ("gross error statistics").

4) Two VAS forecasts (cases A and B) showed little or no improvement over the NOVAS forecasts as measured by gross error statistics, while the forecast error maps inidicated mixed results in both cases.

5) Largest improvements in some forecasts by VAS data were larger than the largest degradations in others.

6) External (barotropic) wave modes excited by large regions of large amplitude initial height differences along the LFM's western boundary appear to be responsible for the occurrence of large-scale, high amplitude 500 mb 48 hour forecast height differences in regions remote from the initial height differences.

7) The preservation of the initial height differences at the western boundary throughout the forecast cycle probably plays a major role in the maintenance of these waves.

8) A case in which the VAS 48 hour forecast was inferior to the NOVAS 48-hour forecast was improved through selectively editing the VAS data and rerunning the analysis-and-forecast system.

Examination of the sequences of forecasts with VAS-NOVAS forecast differences superimposed reveals the considerable complexity involved in ascertaining cause and effect in these experiments. Considering the relative crudeness of the LFM analysis system, the formulation of the boundary conditions, and the problems involved in producing an edited VAS sounding data set, the fact that forecasts were improved, and that any degradations were small, is a remarkable testament to the ability of the hydrodynamic equations, as formulated in the LFM, to make use of the information available in the VAS data to do a reasonably good job in forecasting the atmosphere.

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REFERENCES

Bonner, W., P. L. Lemar, R. J. Van Haaren, A. J. Desmarais, H. M. O'Neil, 1976: A Test of the Impact of NOAA-2 VTPR Soundings on Operational Analyses and Forecasts. NOAA Technical Memorandum NWS NMC-57.

Chesters, D. L. and L. Uccelini, 1983: VISSR Atmospheric Sounder (VAS) Simulation Experiment for a Severe Storm Environment. Monthly Weather Review, 10, 198-216.

Cressman, G., 1959: An Operational Objective Analysis Scheme. Monthly Weather Review, 87, 367-374.

Gerrity, J., Jr., 1978: The LFM Model-1976: A Documentation. NOAA Technical Memorandum NWS NMC-60.

Hayden, C. M., and A.J. Schreiner, 1984: Real Time Meteorological Applications of the Geostationary Satellite Sounder on GOES-6: Battling the Computer, Code, and Clock. Proceedings of SPIE Technical Symposium East, 1984, Volume 481, April 27-May 4, 1984, Arlington, Virginia, pp 100-107.

Newell, J., and D. G. Deaven, 1981: The LFM-II Mocel--1980. NOAA Technical Memorandum NWS NMC-66.

O'Lenic, E. A., 1985: An Evaluation of the Use of VISSR Atmospheric Sounder (VAS) Data in the LFM. Submitted for Monthly Weather Review.

Panofsky, H. A., and G. W. Brier, 1985: Some Applications of Statistics to Meteorology. The Pennsylvania State University, 224 pp.

Smith, W. L., 1970: Interative Solution of the Radiative Transfer Equation for the Temperature and Obsorbing Gas Profile of an Atmosphere. Applied Optics, 9, 1993-1999.

Smith, W. L., and H. Woolf, 1981: Algorithms used to Retrieve Surface Skin Temperature and Vertical Temperature and Moisture Profiles from VISSR Atmospheric Sounder (VAS) Radiance Observations. Preprint Volume: Forth Conference on Atmospheric Radiation, June 16-18, 1981, Toronto, Ontario, Canada. Published by the American Meteorological Society, Boston, Massachusetts.

______, W. E. Suomi, W. P. Menzel, H. M. Woolf, L. A. Sromovsky, H. E. Revercomb, C. M. Hayden, D. N. Erickson, F. R. Mosher, 1981: First Sounding Results from VAS-D. Bulletin of the American Meteorological Society, 62, 232-236.

Teweles, S., and H. B. Wobus, 1954: Verification of Prognostic Charts. Bulletin of American Meteorological Society, 35, 455-463.

Tracton, M. S., A. J. Desmarais, R. J. Van Hiaren, and R. D. McPherson, 1980: The Impact of Satellite Soundings on the National Meteorological Center's Analysis and Forecast System-The Data Systems Test Results. Monthly Weather Review, 108, 543-586.

APPENDIX 1

Larger Versions of Figure 2

FIG 2A

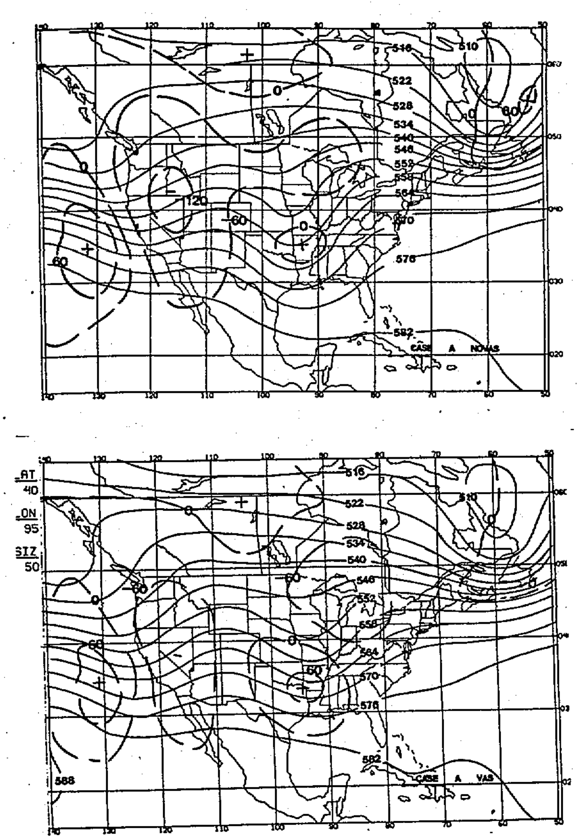

FIG 2B

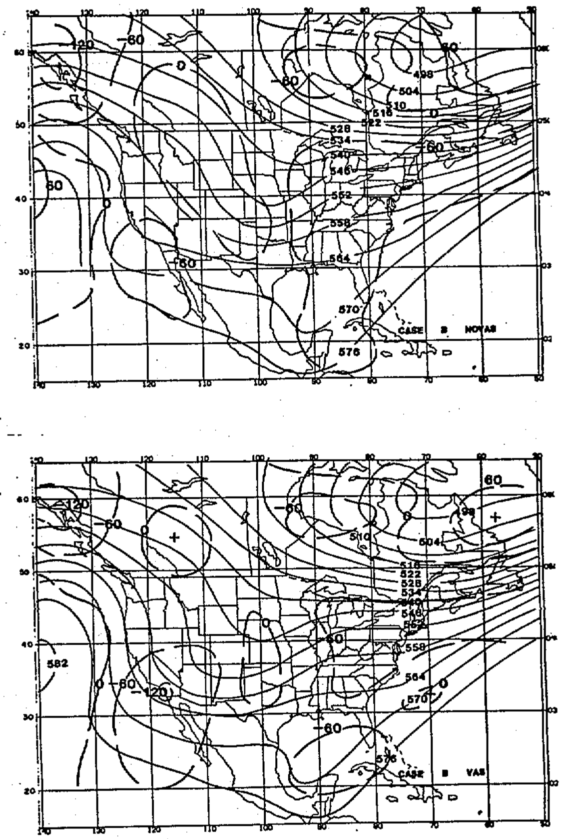

FIG 2C

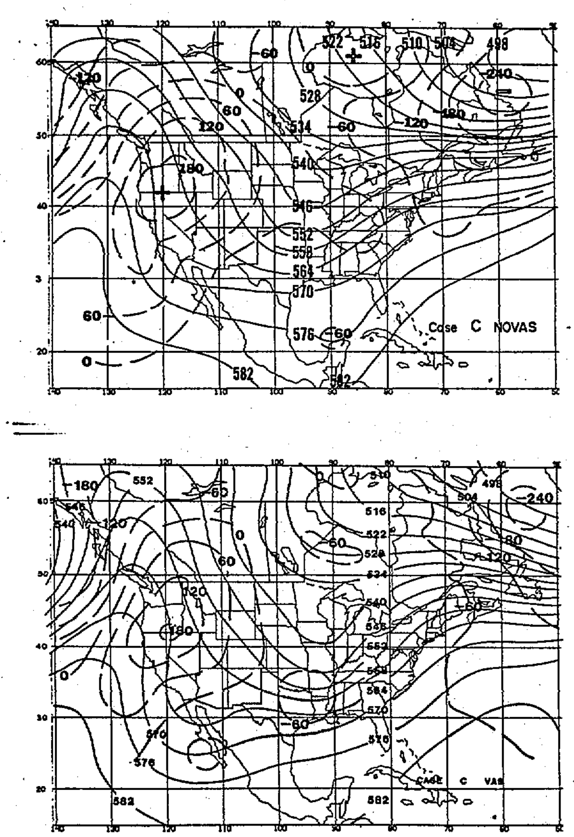

FIG 2D

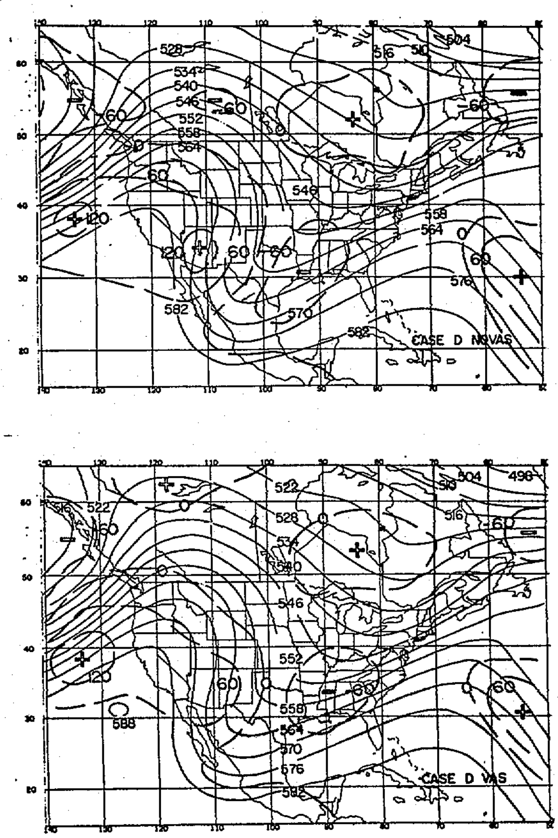

FIG 2

FIG 2E

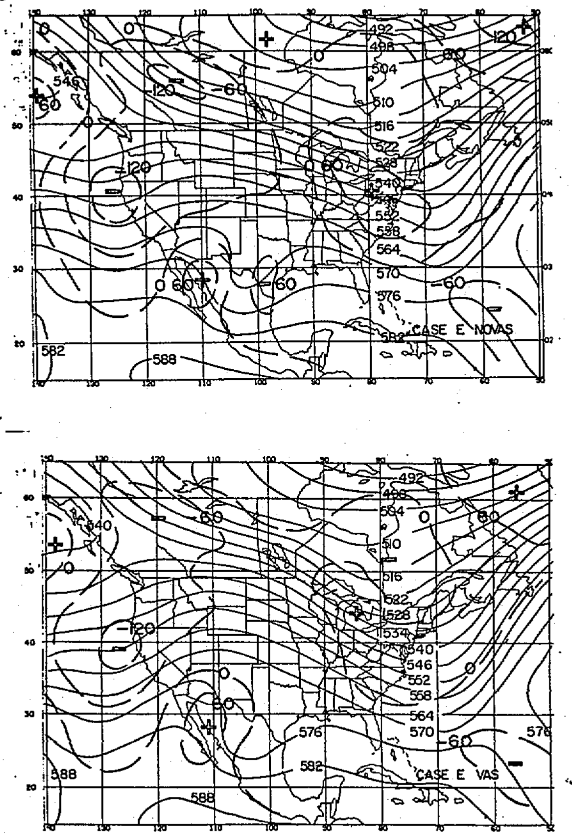

FIG 2F

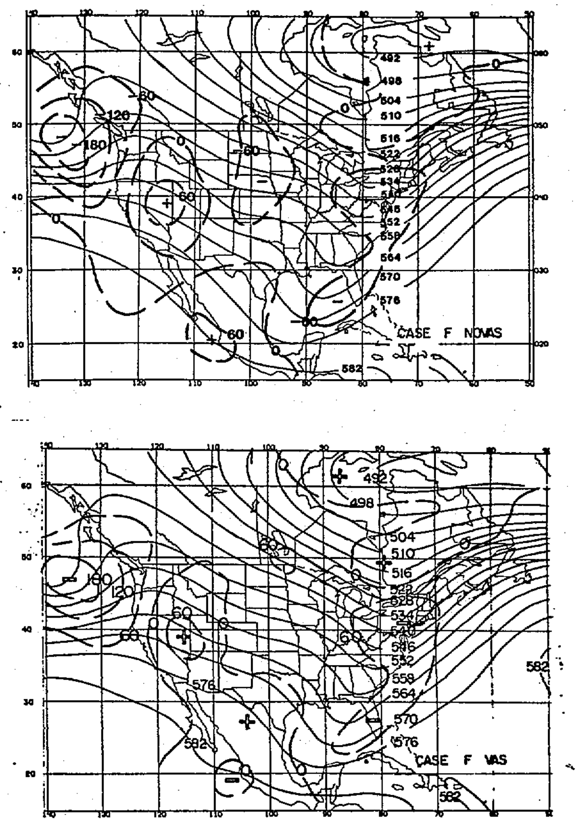

FIG 2G

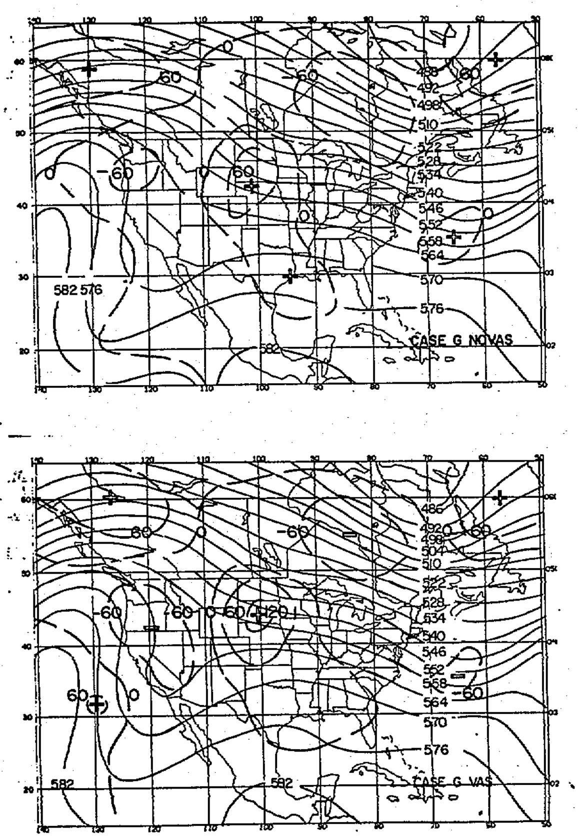

FIG 2H